University of Saskatchewan
Dept. of Electrical Engineering
EE325 Communication Systems I

Midterm Examination - Friday, Feb. 19, 1999

Solution

1(a) Determine the normalized power and level in dBV for the following sinusoidal signals. Complete the following table using one decimal place accuracy. (2 points)

(Revised Question

Signal	Level (dBV)	P norm (Watts)	
700 mV rms @ 1000 Hz	−3	0.5	
10 volts rms @ 256 Hz	20	100	
20 Vp-p sinusoid @ 60 Hz	17	50	$20\,V_{p-p} = 7.07\,V_{rms}$
Sum of above 3 signals	21.8	150.5	← sum power (frequencies differ
Checksum (of all 4 rows)	55.8	301	

1(a) A modulator forms the product of the carrier signal $c(t) = 100\text{ V}\cos 2\pi\, 20000\,t$ and the following signals $m(t)$. Determine the amplitudes and frequencies of the components in the modulated output signal. Assume single sided spectrum for your solution. (2 points)

$m(t)$	A1 (volts)	f1 (kHz)	A2 (volts)	f2 (kHz)	A3 (volts)	f3 (kHz)	A4 (volts)	f4 (kHz)
$2\cos 2\pi 4000t$	100	16	100	24				
$4\cos 2\pi 11000t$	200	9	200	31				
$2+6\cos 2\pi 23000t$	300	3	200	20	300	43	----	----
$\cos 2\pi 4000t + \cos 2\pi 8000t$	50	12	50	16	50	24	50	28
Checksum	650	40	550	91	350	67	50	28

2(a) Which sampling form
sampling ? Explain v

i) Flat top sa

ii) - a narrow
This allows many (narrow) signals in a TDM multiplexer

- a flat top sample has a single value of voltage & only one number needs to be stored in PCM format.

2(b) In a digital transmission system, samples are placed in a digital latch as they arrive and the content of the latch remains until the next sample arrives. The latch is connected to an D/A converter which is followed by an analog lowpass filter.
(i) Does this system implement natural or flat top sampling ? (1 point)
(ii) What is the duty cycle (in percent) of the decoded samples ? (1 point)

i) Flat top sampling

ii) duty cycle is 100%.

2(c) A flat top sampled system has 50% duty cycle pulses prior to the 5 kHz lowpass reconstruction filter. Determine the output amplitude and frequency if the sampling rate is 10 kHz and the input modulation signal is $10\cos 2\pi 4000t$. (1 point)

$$\hat{W}(f) = \frac{\tau}{T}\,\frac{\sin \pi\tau f}{\pi\tau f}\,W(f)$$

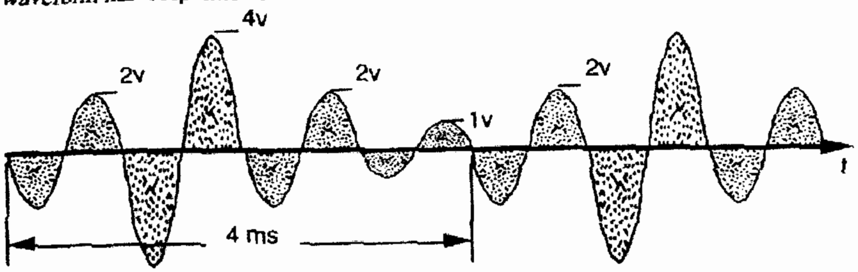
$$\hat{W}(4\,\text{kHz}) = \frac{\tau}{T}\,\frac{\sin \pi\tau (4000)}{\pi\tau(4000)}\,(10)$$

$T_s = 1/f_s = 10$
$\tau = 0.5\,T_s =$

$$A = 4.68\ V_p \text{ at } 4000\ \text{Hz}$$

3 A periodic waveform consists of four 1 ms segments each with one cycle of sinewave. The

sinewave amplitudes in the 4 successive segments are 2v, 4v, 2v, and 1v. The periodic waveform has a repetition rate of 250 Hz and has no discontinuities.



(a) Determine the normalized average power and peak to rms ratio of the waveform. (2 points)

$$\langle P_N \rangle = \frac{1}{4}\left(\frac{2^2}{2} + \frac{4^2}{2} + \frac{2^2}{2} + \frac{1^2}{2}\right) = \frac{1}{4}(12.5) = \boxed{3.125\,W}$$

$$V_{rms} = \sqrt{3.125} = 1.768\,V \qquad V_p = 4\,v$$

$$\frac{V_{Peak}}{V_{rms}} = \boxed{2.263}$$

(b) The above waveform is quantized with an 11 bit encoder/decoder that has a range ±10.24 V. What is the SNR of the quantized waveform? Note that this question does not consider sampling. (2 points)

Solution #1 — $S = \dfrac{2(10.24\,V)}{2^{11}} = 10\,mV$, $P_N = \dfrac{(10\,mV)^2}{12}$

$$SNR\,(dB) = 10\log_{10}\left(\frac{P_S}{P_N}\right) = 10\log_{10}\left(\frac{3.125\,W}{8.33\mu W}\right) = \boxed{55.74\,dB}$$

Solution #2 Full load sinusoid $SNR = 6.02(11) + 1.77$

$$SNR = 67.99\,dB$$

$$SNR\,(dB) = SNR_{FLSW} + 10\log_{10}\left(\frac{P_S}{P_{FLSW}}\right)$$

$$= 67.99 + 10\log_{10}\left(\frac{3.125}{(10.24)^2/2}\right) = \boxed{55.74\,dB}$$

Solution #3

$$SNR\,(dB) = 67.99 + \underbrace{20\log_{10}\left(\frac{4\,V}{10.24\,V}\right)}_{-8.16\,dB \text{ underloading}} - \underbrace{20\log\left(\frac{2.263}{\sqrt{2}}\right)}_{-4.08\,dB \text{ waveform}} = \boxed{55.7\,dB}$$

4. A 5 Vrms full load sinusoid with frequency 1000 Hz is to be quantized, coded and sent by digital transmission. Assume that the system bandwidth is 4 kHz and the sampling rate is 32 kilosamples per second (32 ks/s).

(a) What is the decoded SNR if 8 bit LPCM is used? (1 point)

$$SNR\,(dB) = 6.02(8) + 1.77 + 10\log_{10}\left(\frac{f_s/2}{f_{bw}}\right)$$

$$= 49.93 + 10\log_{10}\left(\frac{32000/2}{4000}\right) = \boxed{55.95\,dB}$$

(b) What is the decoded SNR if Delta Modulation is used? (1 point)

$$SNR = \frac{3f_s^2}{8\pi^2 f_m^2}\cdot\frac{f_s/2}{f_{bw}} = \frac{3(32000)^2}{8\pi^2(1000)^2}\cdot\frac{16k}{4k} = 155.6$$

$$SNR\,(dB) = 10\log_{10} 155.6 = \boxed{21.92\,dB}$$

(c) What is the decoded SNR if 4 bit linear DPCM is used? (1 point)

$$SNR\,(dB) = SNR_{DM@32kHz} + 20\log_{10}(2^4 - 1)$$

$$= 21.92\,dB + 23.52\,dB = \boxed{45.44\,dB}$$

(d) What is the quantizing bin size (in volts) for the above three cases? (1 point)

a) $V_{rms} = 5\,V \Rightarrow V_{P\text{-}P} = 14.14\,v$ $\quad S = \dfrac{14.14\,V}{2^8} = \boxed{55.2\,mV}$

PCM

b) Delta Mod. at full Load $\quad A_{max}\,W_m = S f_s$

$$S = \frac{5\sqrt{2}\cdot 2\pi\,1000}{} = \boxed{1.388\,V}$$

32,000

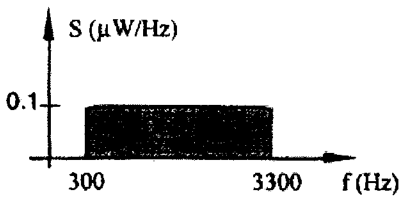
c) DPCM $\quad A_{max} W_m = S(2^4-1) f_s$ at full load

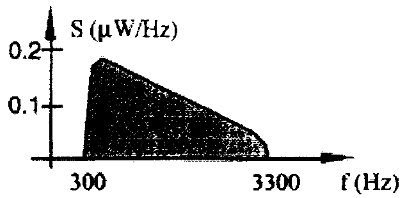
$$S = \frac{1388\,mV}{15} = \boxed{92.56\,mV}$$

5(a) The (normalized) power spectral density of a voice signal and a 33.6 kb/s data signal are shown below.

(i) Estimate normalized power and the level in dBV for each signal. (2 points)

(ii) Comment why one signal is easier to transmit using delta modulation (1 point)





i) $P_N = (0.1\,\mu W/Hz)(3000\,Hz) = \boxed{300\,\mu W}$ $\qquad P_N = \left(\frac{0.18+0.02}{2}\right)(3000) = \boxed{300\,\mu W}$

$V_{rms} = \sqrt{300\,\mu W} = 17.3\,mV$ $\qquad V_{rms} = \sqrt{300\,\mu W} = 17.3\,mV$

Level $= 20\log_{10}(17.3\times10^{-3}) = \boxed{-35.2\text{ dBV}}$ $\qquad$ Same $\boxed{-35.2\text{ d}}$

ii) The voice signal will be less prone to slope overlo since the high frequencies have lower amplitude and this reduces the maximum rate of change i the signal. Step size can be smaller which yield higher SNR.

5(b) Assume a Mu Law encoder with minimum quantizing bin of 384 uV. Determine the 8 bit codeword which best represents a voltage sample of +100 mV. (1 point)

$$\text{sample value} = \frac{100\,mV}{384\,\mu V} = 260.4 \text{ units}$$

Mu law exponent (or segment) $\quad E = \text{Int}\left\{\log_2\left(\frac{260.4+16.5}{\ }\right)\right\}$

$= \text{Int}\{\log_2(16.7)\} = 4$

To find Mu law mantissa $\quad 260.4 = 2^4(M+16.5)-16.5$

$M+16.5 = \frac{260.4+16}{2^4} = 17.3 \Rightarrow M = \text{Round}\{0.8\} = 1$

Sign = 0 (there is an error in the notes!)

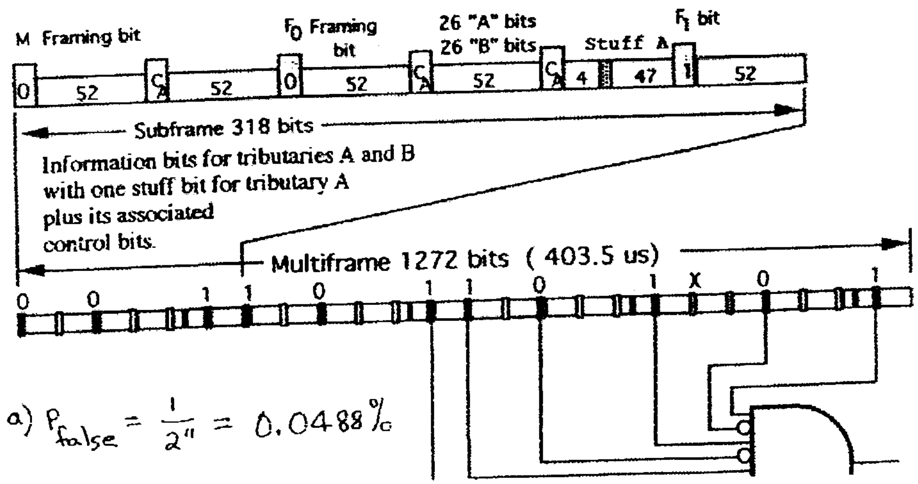
Result $\Rightarrow \boxed{0\ 100\ 0001}$ → You can also look this up in the table.

6. The framing circuit in the receiver of a DS1-C transmission system observes 11 bits from 1272 bit history. Note that the X framing bit is not defined as "1" or "0". The observed bits are at the framing bit intervals illustrated in the frame illustration below. Assume tha the input (tributary) DS1 data bits are random.

(a) Determine the probability of any specific sample of 11 data bits being mistaken for framing bits. (1 point)

(b) Estimate the time required to find frame synchronization assuming that there are no channel errors (the true framing are always recognized when they are observed in th correct order by the detector) (2 points)

(c) At what frequency do the stuff bits for channel A occur? (1 point)



a) $P_{false} = \frac{1}{2^{11}} = 0.0488\%$